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STUDY FOR NASA/MSFC. PHASED  
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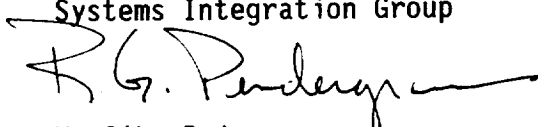
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Marshall Space Flight Center, AL 35812

Attn: Mr. M. Watson/E035

Subject: Contract No. NAS8-37745  
Phased Development Plan  
Simulation Computer System for Space  
Station Program

In accordance with the requirements of the subject contract,  
the technical report titled Phased Development Plan is  
herewith submitted and distributed as shown.

TRW Inc.  
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Contracts Administrator  
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SPACE STATION SIMULATION COMPUTER SYSTEM (SCS)  
STUDY

PHASED DEVELOPMENT  
PLAN

SCS

SCS



SCS

SCS

CDRL: TRW-SCS-90-XT3

7 December, 1990

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## 1.0 Overview

The Simulation Computer System (SCS) consists of the computational hardware and software which supports the Space Station Freedom (SSF) Payload Training Complex (PTC) to be located at the Marshall Space Flight Center (MSFC). The PTC contains 2 U.S. Lab module trainers, Part Task Trainers (PTTs) for JEM and Columbus, PTTs for the U.S. Lab, an IT&V facility, and a development facility. Figure 1-1 pictures the PTC configuration and identifies the SCS components. The SCS provides all the hosts, peripherals, networks, and associated SCS software to operate the various trainers and facilities.

## 2.0 Scope

This plan is intended to document an approach for the phased development of the SCS within the constraints of the overall SSF Program schedule. One major objective of this plan is to show the required time frames for hardware availability to support the SCS development. This phased development plan is based on the SCS configuration pictured in Figure 1-1.

## 3.0 Groundrules

The following groundrules were used in the development of this plan:

- 1) This plan addresses the current high-level SSFP milestones by providing training capabilities 18 months prior to launch of a specific SS element. The plan provides an idealized schedule based on SSFP milestones.
- 2) One U.S. Lab trainer must be available to support the Lab launch date, the JEM and ESA PTT must be available to support the JEM and Columbus launch dates, additional trainers must be available to support AC.
- 3) There will be DMS Kits available for all U.S. trainers and test facilities in the SCS which eliminates the development of any U.S. non-DMS Kit trainer.
- 4) GFE items were assumed to be available when needed for the SCS development schedule.
- 5) Major pieces of equipment will be procured at the latest reasonable time frame to support the development activity.
- 6) The SCS development will follow the SSE standards.
- 7) The plan will address the current PTC/SCS configuration as illustrated in Figure 1-1.

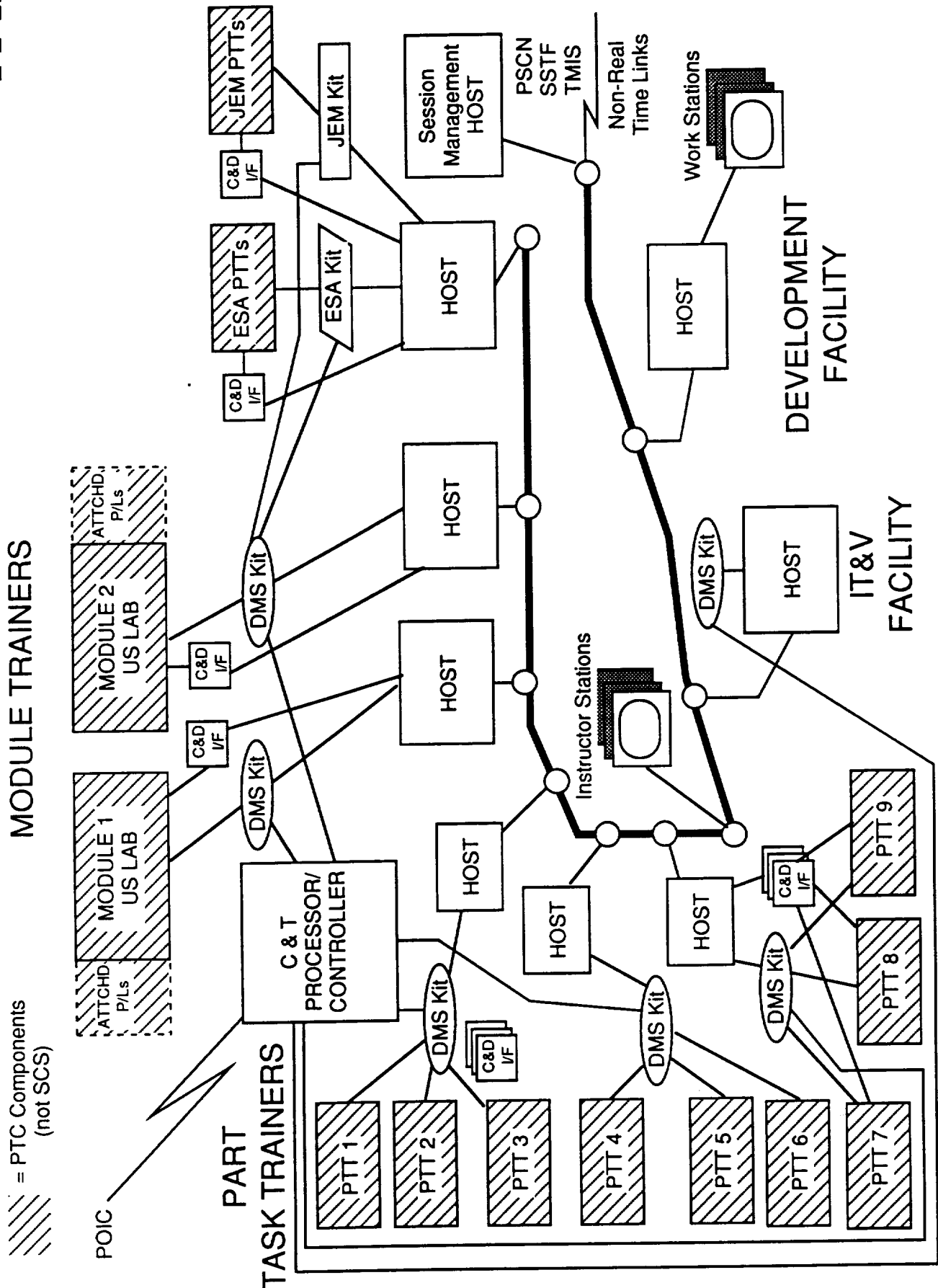


Figure 1-1. SCS REFERENCE CONFIGURATION

## 4.0 Phased Development Plan

The phased development plan is documented in the following paragraphs in terms of the different development activities. The overall SCS schedule is pictured in Figure 4-1, which includes the related SSFP milestones. The SCS development plan calls out three basic development time frames which is the PMC time frame, an intermediate time frame, and the AC time frame. This division of work is based on the need dates for SCS and the desire to spread the work and cost over the next several years. By developing only those systems that are necessary in the PMC time frame, a reasonable schedule is maintained for the initial SCS development since the first development would be expected to experience the most programmatic and technical difficulties. Due to the commonality between the systems, most of the PMC hardware and software development is incorporated in the systems developed in later time frames. The staggered schedule allows time for the resolution of all problems discovered in the common hardware and software during the test program prior to use in the other systems.

These three identified time frames allows the development of some systems to be combined to make the process more efficient than having an independent cycle for each system while spreading the effort in a reasonable manner. The U.S. Lab #1 trainer and the IT&V facility will be developed during the PMC time frame. A U.S. Lab trainer must be available in this time frame to support the Lab launch and the IT&V facility must be available to support payload model testing and development which is scheduled to begin in 1995. Due to the time lag between the Lab launch and the IP module launches (the next trainers needed to support the program), an intermediate development cycle was identified. This development will include both the IP modules since their launch dates are only six months apart. The final development for the AC includes the additional U.S. trainers (U.S. Lab #2 and the U.S. PTTs) which are necessary to support AC training.

The schedules for each of these development cycles are documented respectively in the network charts of Figures 4-2, 4-4, and 4-6 and the gant charts in Figures 4-3, 4-5, 4-7. The following paragraphs provide the explanation of the schedule and more details concerning procurement of supporting hardware. All references to the SCS software include that software identified to support SCS operations (i.e. simulation executive, development tools, etc.). The term "simulation software" refers to the simulations that are being developed external to the SCS effort and will be integrated into the SCS for execution (i.e. system, environment, and payload models).

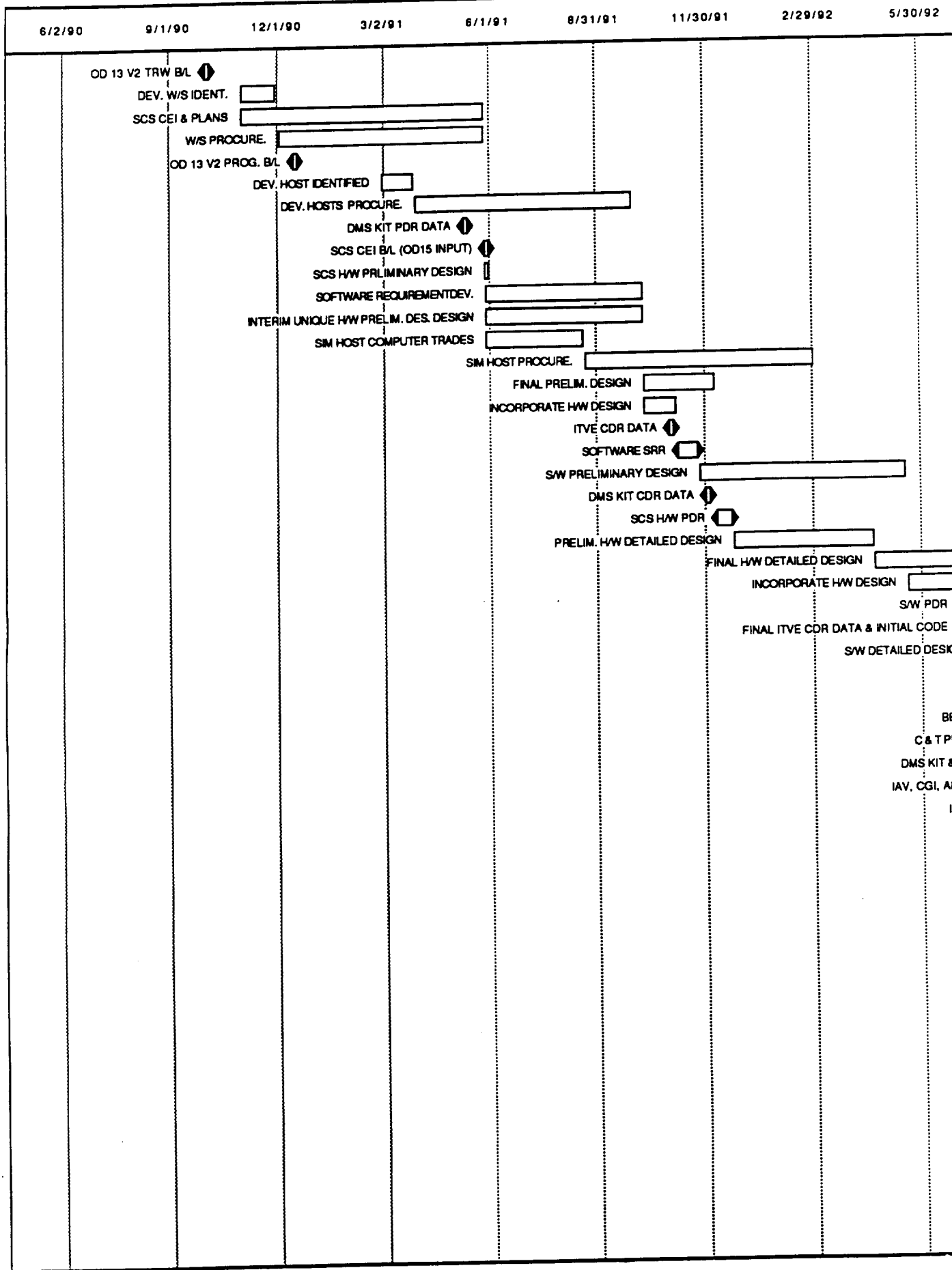
### 4.1 Methodology for Plan Development

The majority of the plan was laid out based on past experience in system development and the critical path method scheduling approach. An analysis of the overall job identified the tasks and their interdependencies, which will be discussed in the following paragraphs. Secondly, the task timeline was tailored to fit into the time frame between the availability of the PTC functional requirements (the logical starting point for SCS development) and the need dates for the various SCS components.

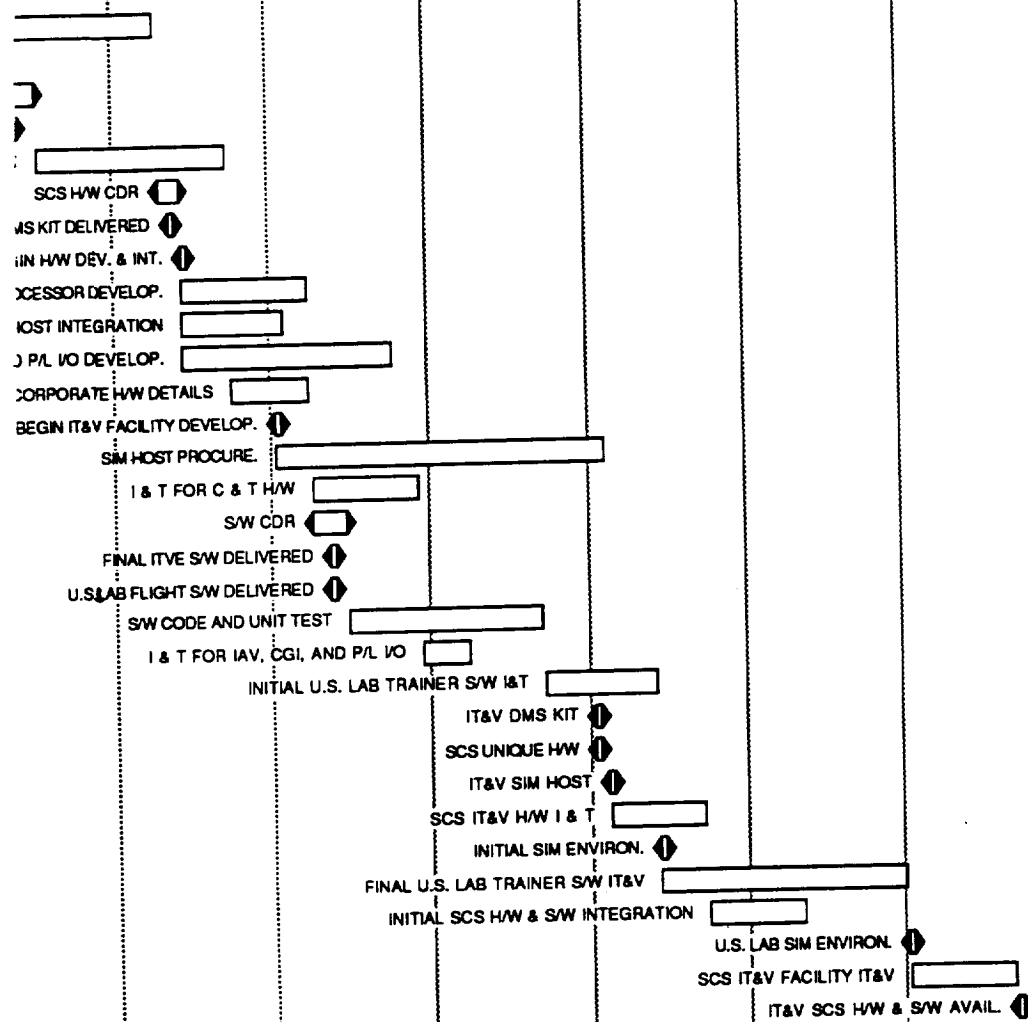
FY	1991				1992				1993				1994				1995				1996				1997				1998				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
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PROGRAM MILESTONES	LO PPR ▽	PTC PPR ▽			LO PPR ▽	PTC PPR ▽			LO PTC CDR CDR ▽				AO PTC PPR ▽	PTC PPR ▽																			PTC AC CDR ▽
SCS MILESTONES *	SCS ACQ ▽	SCS SPEC ▽											U.S. LAB 1 FACILITY ▽	ITV FACILITY ▽			SEA PTT ▽																U.S. LAB 1 PTT ▽
U.S. LAB #1 DEVELOPMENT					U.S. LAB 1 PPR ▽	U.S. LAB 1 PPR ▽							SCS ACQ ▽																				
ITV FACILITY DEVELOPMENT																																	
INTERNATIONAL PARTNER PTTG DEVELOPMENT																																	
U.S. PTT DEVELOPMENT																																	
U.S. LAB #2 DEVELOPMENT																																	

\* The SCS milestones show the availability of the SCS components for the designated trainers. The actual availability will be approximately one year later to accommodate the integration of system simulation software, trainer racks, and other facility hardware.

# Figure 4-1. HIGH LEVEL SCS SCHEDULE



8/29/92 11/28/92 2/27/93 5/29/93 8/28/93 11/27/93 2/26/94



2  
FOLDOUT FRAME

IT CHART

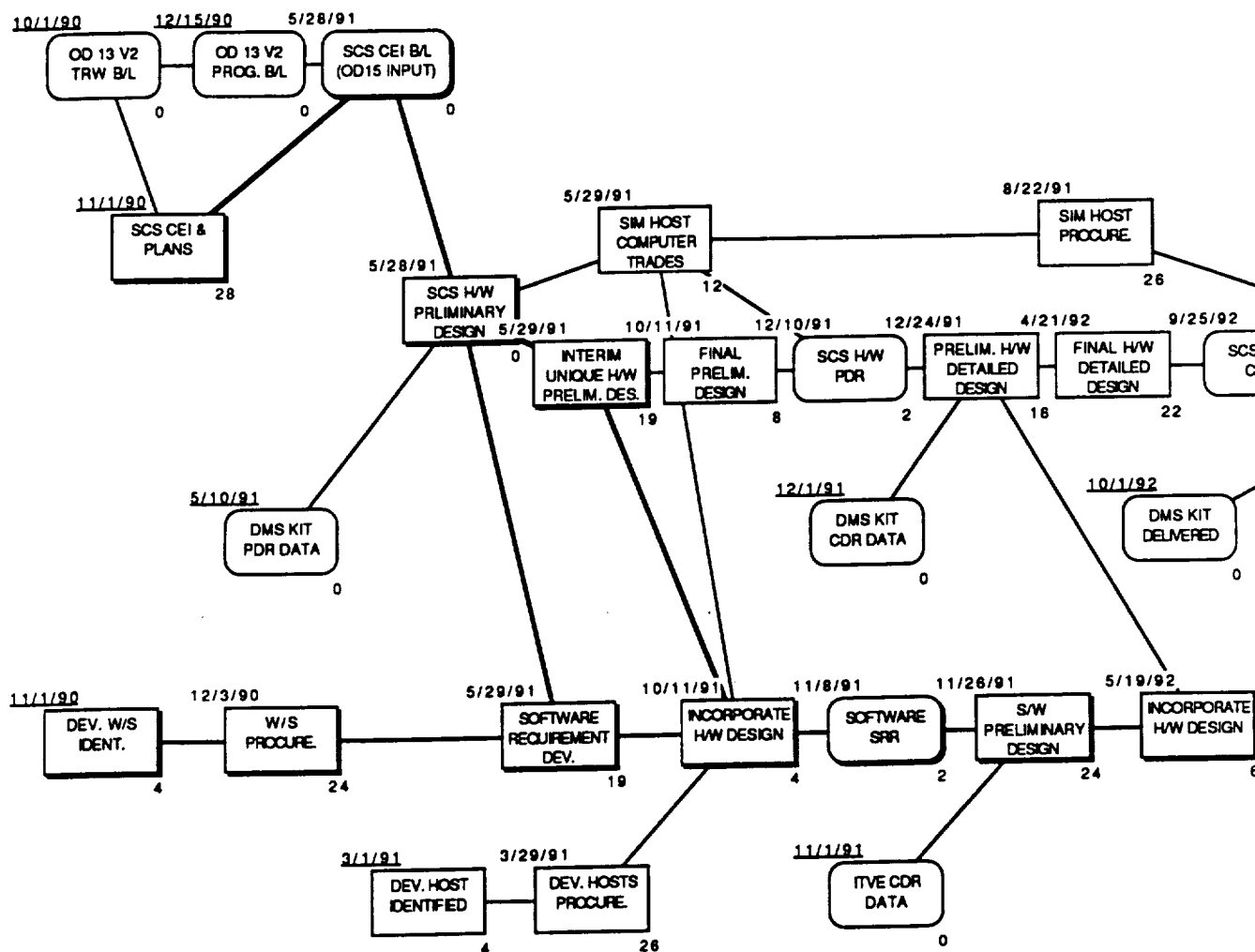
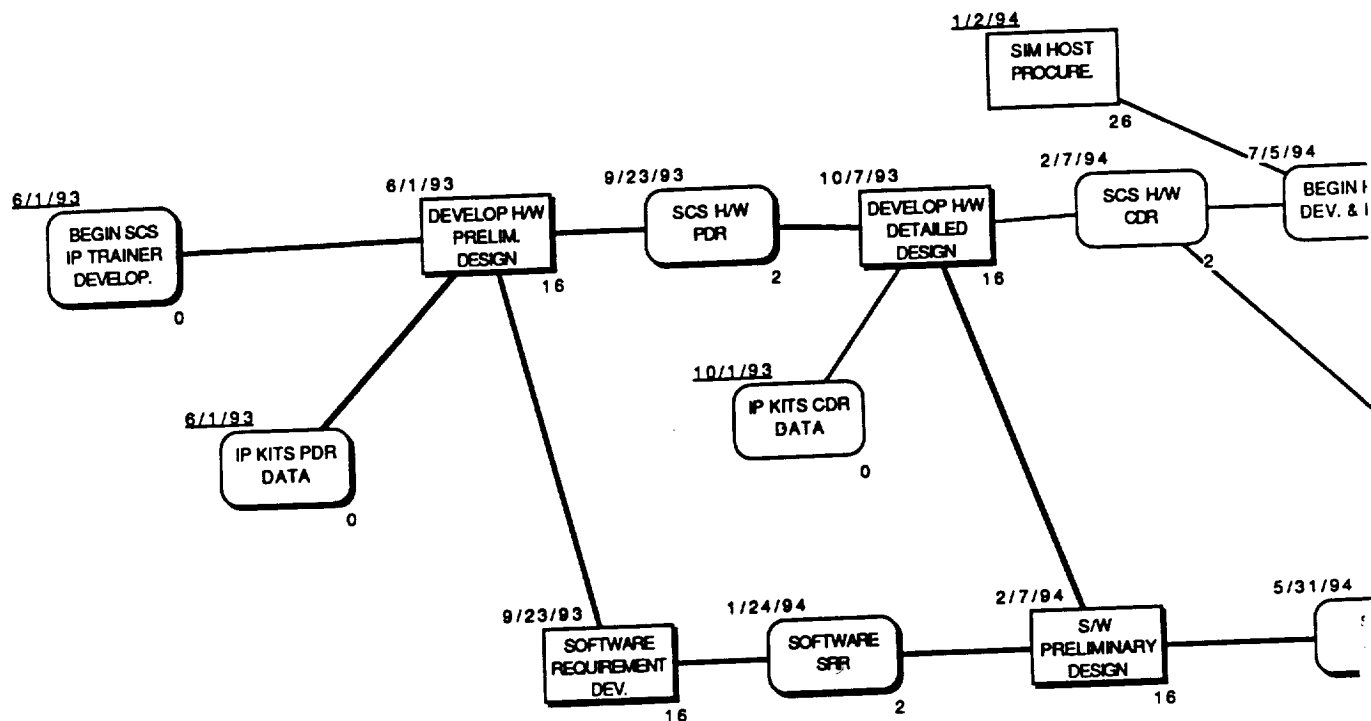
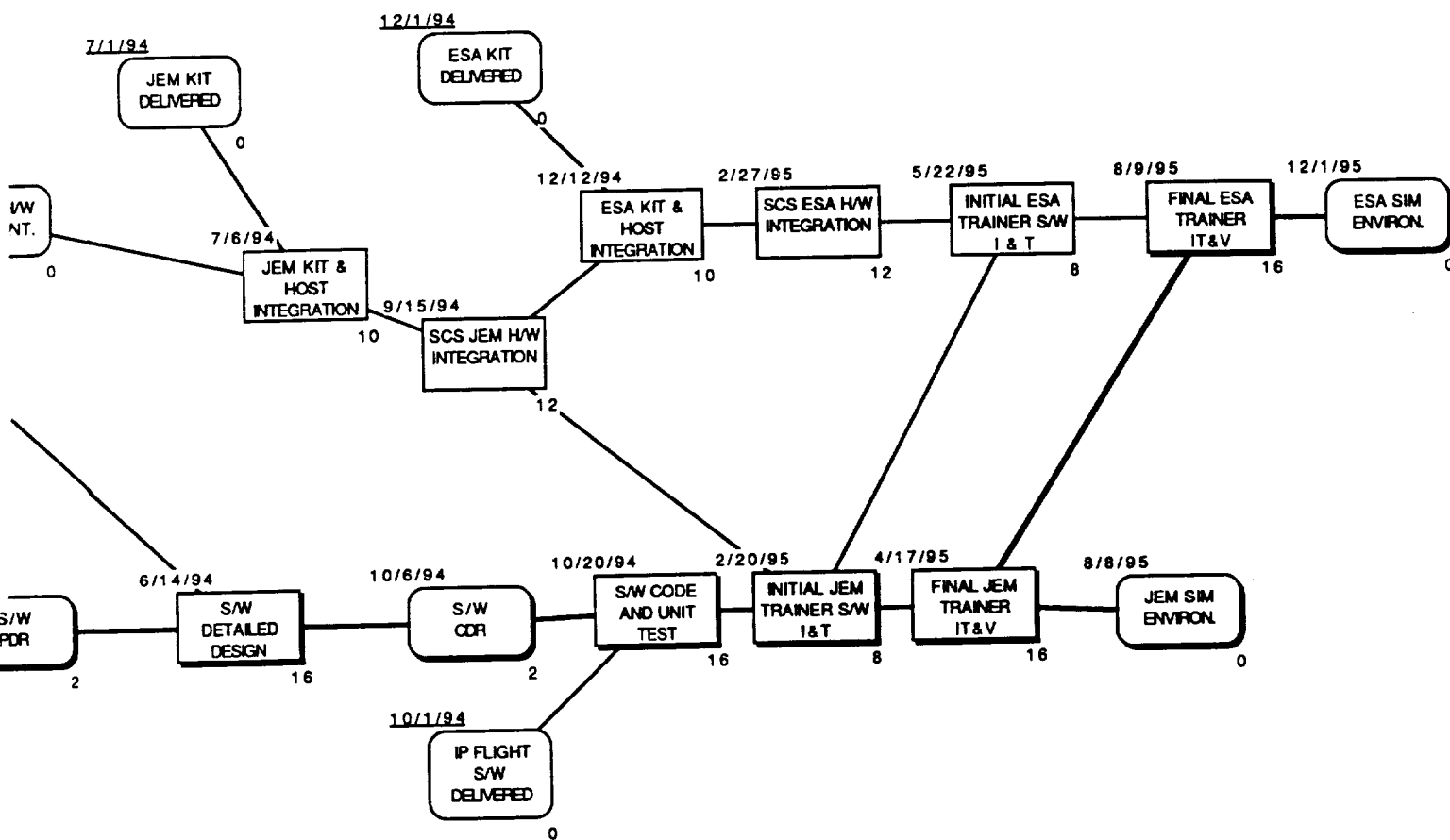


Figure 4-2. PMC SCS DEVELOPMENT NETWORK



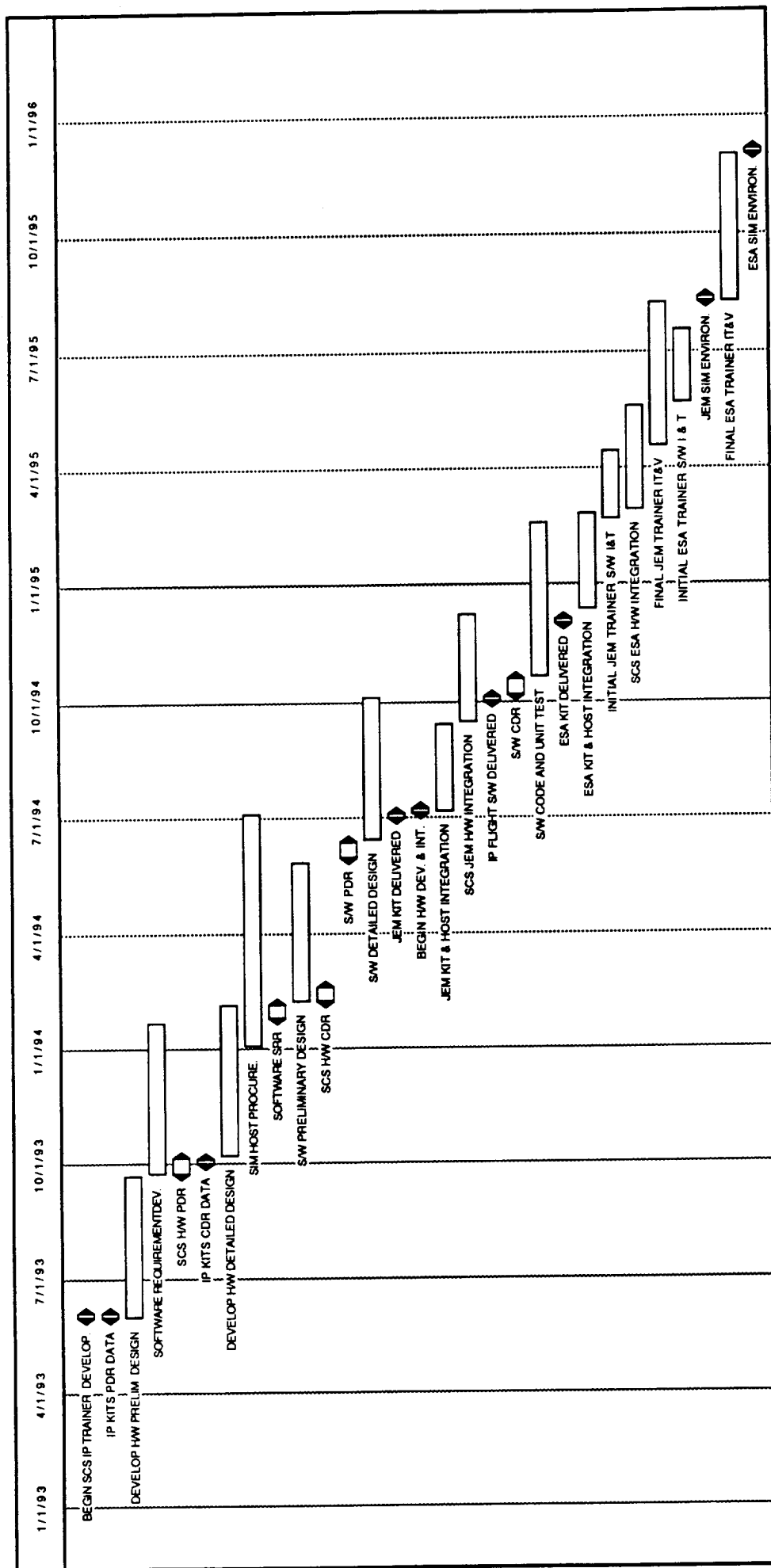


**Figure 4-4. INTERMEDIATE SCS DEVELOPMENT NETWORK CHART**



ENT

FULBOUT FRAME 2



**Figure 4-5. INTERMEDIATE SCS DEVELOPMENT  
GANTT CHART**

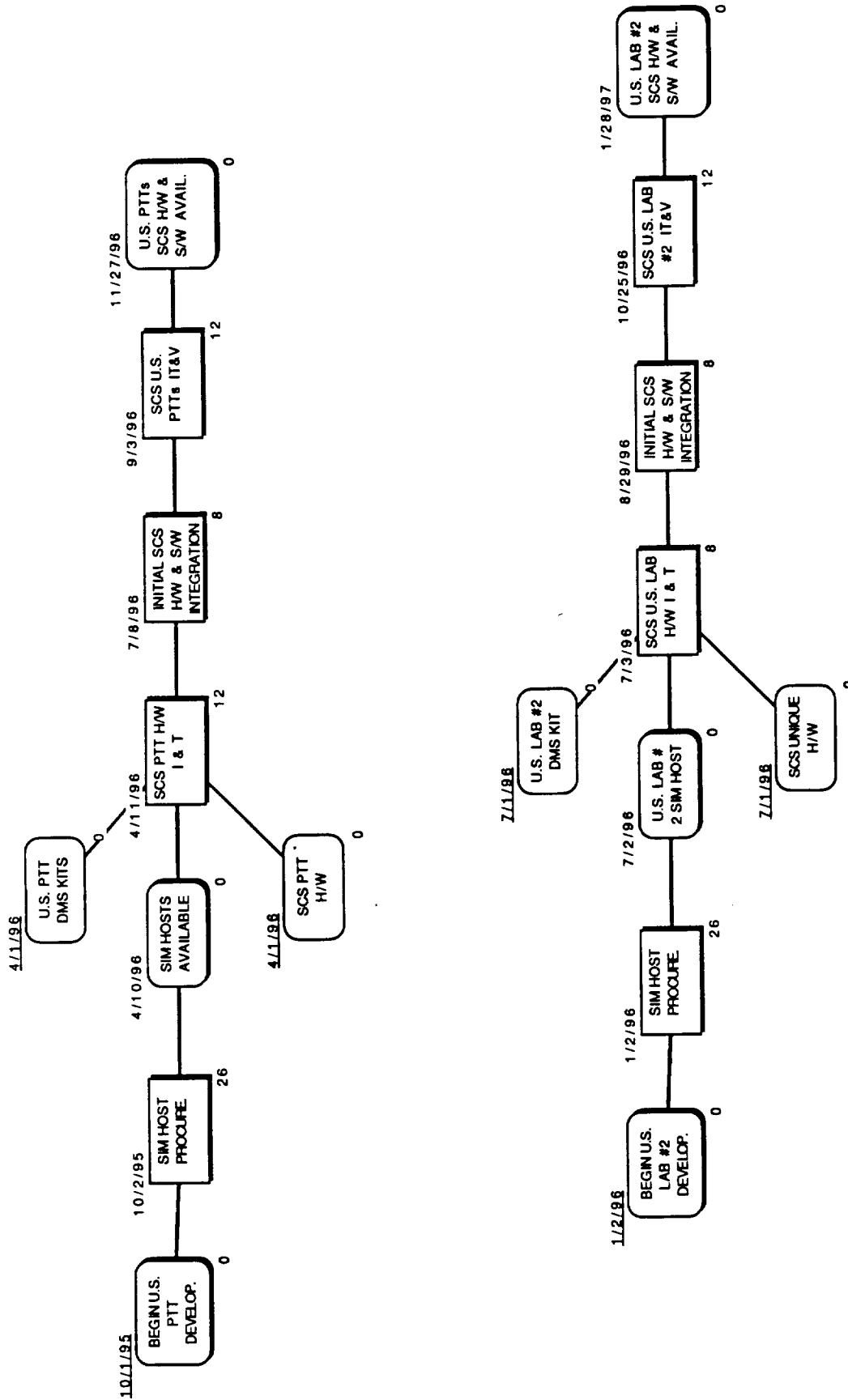


Figure 4-6. AC SCS DEVELOPMENT NETWORK CHART

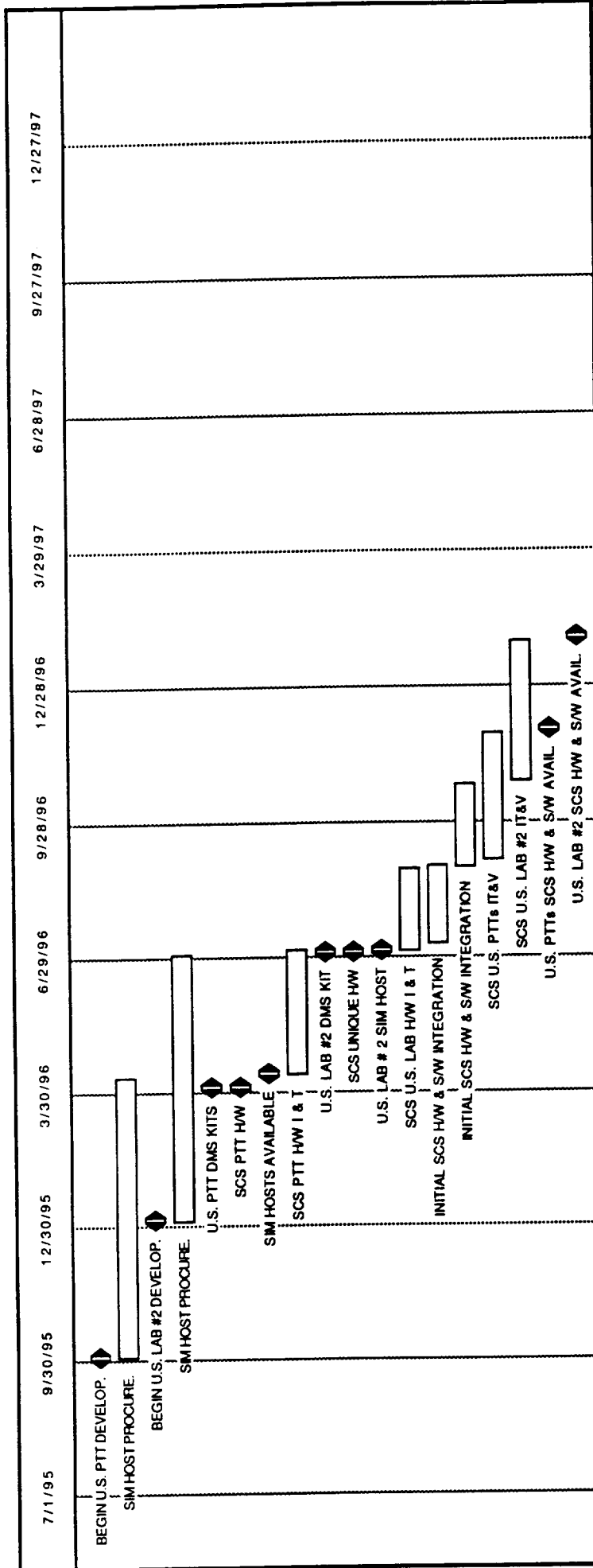


Figure 4-7. AC SCS DEVELOPMENT GANT CHART

The need dates are based on the 18 month lead time prior to element launch dates and an additional 12 months allowed for the integration of PTC elements with the SCS elements. There will be a hardware/software development cycle with an integration phase for SCS elements which is followed by continuing integration of PTC simulation software and PTC hardware (SS racks and mockups).

For this exercise, external inputs (GFE items) were assumed to be available when necessary for the SCS schedule. These inputs are critical to the SCS schedule and delivery delays would cause schedule impacts. The timely delivery of the U.S. GFE items are not expected to be a problem. However, there is currently little insight into the schedule for the International Partners (IP) and there is some risk anticipated with the IP GFE item deliveries. The following is a list of identified GFE items and the SCS development activity that they must support:

- 1) DMS Kit and IP Kit preliminary design (or detailed design if available) to support SCS hardware preliminary design.
- 2) DMS Kit and IP Kit detailed design (or as-built documentation if available) to support SCS hardware detailed design.
- 3) DMS Kits and IP Kits delivered to support SCS hardware integration.
- 4) ITVE software CDR data to support the SCS software preliminary design.
- 5) ITVE software final detailed design and majority of code to support the SCS software detailed design.
- 6) All final ITVE software delivered by the beginning of the SCS coding phase.
- 7) Flight software for U.S. Lab and IP Modules necessary to support training must be delivered by the code/unit test phase for SCS software.

The DMS Kit and ITVE items would all apply to the initial PMC development cycle, but the IP items would apply to the intermediate development time frame.

The final schedule was developed with a scheduling tool (MacProject) to perform the critical path analysis. This allowed us to identify all tasks in which any delays would effect the external need dates. The critical paths are recognizable as the bolder paths and boxes in the network charts of Figures 4-2, 4-4, and 4-6. The software schedule was also confirmed via the use of the COCOMO model based on the estimated lines of code for the SCS. Only minor discrepancies were identified which indicates that the software schedule is appropriate for this development effort.

## **4.2 SCS Contract End Item (CEI) Specification**

The first activity that must be accomplished is the development of the SCS CEI Specification. This document will be developed based on the PTC Functional Requirements and will incorporate refinements of the SCS Study Concept Document, MSFC-SPEC-1764 V1.3, 24 Sept. '90. The current requirements will be refined to

provide more detail that will be the baseline for the development of hardware design and software requirements. SSE word processing and requirements generation tools should be available to support this activity.

#### **4.3 Hardware Development and Integration**

The hardware preliminary design will begin at completion of the SCS CEI Spec and culminate in a Preliminary Design Review (PDR). Since the SCS software requirements are being developed concurrently, the hardware personnel will provide design information as it is available to the software requirements personnel. The detailed design will be developed and presented in a Critical Design Review (CDR). Once again, any design details that impact SCS software design will be communicated to the software personnel for incorporation. During this time frame, items will be identified for procurement to allow these items to be available early in the hardware integration phase.

The hardware integration will begin following the CDR and initially consists of the integration of procured hosts with the GFE hardware. Any actual custom development of hardware or customization of COTS hardware will begin immediately following the CDR and will be integrated with the systems as each component is completed. As the integrated systems become available, the software personnel will begin the integration of the SCS software on the target environment.

Although the hardware development process will be equivalent for the PMC and intermediate developments, the majority of the custom design will be developed for the PMC capability. This is due to the fact that the interface to the facility, the interfaces for the instructors, and other such functions that must be consistent among all the trainers will be designed with the initial system. The development for the AC will simply be an integration phase without the design activities and the associated reviews.

There are a number of inputs necessary for the hardware development activities. During the PMC development, the ITVE design documentation must be available to support the hardware development since the SCS design is based on the ITVE architecture. Also, the design data for the DMS Kits must be provided to the hardware developers. All preliminary design information must be available by the start of the hardware preliminary design activities in 5/91. All DMS Kit CDR data must be available by 12/91, when the detailed design activities begin. For the intermediate development, the PDR data for IP Kits must be available at the start of the hardware preliminary design (6/93) and the CDR data provided prior to the start of the hardware detailed design activities (10/93). These are the latest acceptable time tables, but earlier availability will help ensure compatible designs and reduce the risk to the program. The optimal schedule for design data delivery would call for all detailed design (as-built design if available) data by the beginning of the preliminary design activities.

The hardware development and integration must be supported by the availability of the appropriate host and peripherals for any particular trainer or test facility. Although each of the development cycles do not specifically call for the availability of all hardware at the beginning of the initial hardware integration phase, there are

advantages to actually procuring all hardware for each development time frame at the same time. These dates are 10/92 for the PMC development, 7/94 for the intermediate development, and 4/96 for the AC development. Although some limited phasing could occur over several months in each time frame, it is expected to be more efficient to go through the procurement cycle once for the equipment necessary for each development cycle. By procuring all the commercial equipment and requesting GFE equipment at the beginning of the integration effort, the risk of delays or inefficient use of personnel will be greatly decreased since parts of the integration can be performed concurrently. Another advantage with having all of the equipment is that down time due to hardware failures or related problems can be very limited or practically eliminated. In other words, the availability of the equipment provides a great deal of flexibility in managing the development effort. Whatever phasing may be absolutely necessary due to programmatic constraints, one DMS Kit must be available in 10/92 to support the initial development which includes the initial integration of the DMS Kit with the host equipment, integration of the C&T processor equipment, and integration of the IAV equipment. These activities will all be the first SCS integration efforts and must be supported in a timely manner with the availability of a Kit.

#### **4.4 SCS Software Development**

The SCS software development cycle consists of the development of requirements, preliminary design, detailed design, code and unit test, and an initial integration. The requirements will be developed and presented at a Software Requirements Review (SRR) with the requirements spec. The preliminary design is developed from the requirements and presented at the software Preliminary Design Review (PDR) with the first drop of the software design document. The preliminary design is then refined to define the details necessary to support coding and is presented at the software Critical Design Review (CDR) with a new drop of the software design documentation. The software is then coded on the development hosts and unit testing is performed in that same environment. In some cases where hardware is critical to performing a meaningful unit test, the target hardware configuration should be available during the later portion of the code/unit test phase to accommodate limited use by software personnel. Following the code/unit test activities, an initial, informal integration phase occurs in which all the software is integrated and tested. This initial integration will be completed by the software personnel on the target environment to eliminate initial problems prior to beginning the formal verification and validation testing.

Like the hardware, software development will occur during the PMC and intermediate time frames. However, the largest amount of software will be developed for the PMC capabilities since much of the software will be reused in the other systems. The AC development will only incorporate the software integration on the final trainers and the appropriate testing of the system.

Since portions of the ITVE software are planned for use in the SCS, deliveries of the software design information and code are necessary to support the SCS software development. The current schedule for the ITVE software incorporates incremental CDRs of which 3 out of 4 will be completed in time to support the PMC software preliminary design activities (11/91). The final incremental CDR data and the majority

of the ITVE code must be available for the detailed design of the PMC software in 7/92. All ITVE software must be available by the beginning of the coding phase for the PMC development in 1/93. The design of the trainer will incorporate some flight software and some of that software (such as the C&T software) is not expected to be delivered with the DMS Kits. Any flight software that is not delivered with the DMS Kits which is mandated by the trainer design must be provided by 1/93 to support the unit testing of SCS software. The same may be true of system software for the IP modules which must be available for unit testing in the intermediate development (10/94). This flight software is mandatory for testing purposes in cases where the use of the actual flight software is an integral part of the SCS design. In the case of the system models, the model software is essential to the actual training functions but is not essential to the testing of the SCS. Since the SCS design simply accommodates various system models of different fidelity, simple test versions of the models created by the SCS developers will suffice to support the test program.

The development facility is made up of multiple hosts and workstations which support varying activities in the development cycle. SSE-compatible workstations will be the first equipment necessary to support the requirements development which by this plan would be in (11/90). Any other SSE selected hosts or equipment that support the production of Software Requirements Specifications and Interface Requirements Specifications would be necessary approximately 9/91, a few months prior to the Software Requirements Review (SRR). Any remaining development facility equipment necessary to support the development of the software design and code would be required in 12/91 prior to the completion of the SRR.

#### **4.5 System Verification and Validation**

The verification and validation (V&V) plans and procedures will be produced during the requirements and design phases. The actual testing activities will begin following the initial integration and testing of the hardware and software. The testing will begin with the U.S. Lab trainer host system which will validate much of the code that will be common in other facilities. Since this process is scheduled to be completed prior to testing on the other systems, this will allow personnel to resolve problems with common system tests prior to attempting to execute the tests on the other systems. Test execution and results will be documented and provided as inputs to the acceptance decision for the system.

#### **5.0 Summary**

This phased development plan supports the current SSFP schedules and provides an adequate schedule for the SCS development. The three separate development time frames provide the most reasonable division of the tasks to spread the cost over the years of the program. Although there is not any slack built into the schedule, it is believed to be a medium risk schedule which should be able to absorb small impacts caused by the normal difficulties anticipated with a development of this size.

A large part of the development costs are incurred in the PMC phase due to the amount of software that will be developed to support the initial system in addition to the initial hardware development. This plan pushes as much of the development costs into later years as is reasonably possible. Further refinement of the plan could provide a more detailed phasing of equipment procurement, but further deferment of costs will be very limited.



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16. Abstract <p>NASA's Space Station Freedom program (SSFP) planning efforts have identified a need for a payload training simulator system to serve as both a training facility and as a demonstrator to validate operational concepts. The envisioned MSFC Payload Training Complex (PTC) required to meet this need will train the Space Station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be onboard the Space Station Freedom. The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex at MSFC.</p> <p>The purpose of this SCS Study is to investigate issues related to the SCS, alternative requirements, simulator approaches, and state-of-the-art technologies to develop candidate concepts and designs.</p>					
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